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ABSTRACT

The faculty of Denison University have been making heuristic use of gaming and simulation for several years. In the fall of 1974, the college was awarded nearly $300,000 from the Lilly Endowment to continue and expand that heuristic use. Three years later, forms of simulation are being used by fifty per cent of the Denison faculty, and the college is becoming a center for the study of college-level applications of simulation. Four major topics related to the Simulation Project are discussed: (1) how the simulation concept has been defined for widest interest and applicability; (2) how simulation can be linked to a problem-solving approach to learning; (3) a short case history of how the previous two formulations were integrated in an extensive way into a traditional college curriculum; and (4) methods of evaluating these simulation efforts, with respect to validity and teaching effectiveness. (Author/HV)

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The Denison Simulation Project: Formulating, Introducing, and Evaluating Curricular Change

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The Denison Simulation Project: Formulating, Introducing, and Evaluating Curricular Change

ABSTRACT

Many faculty at Denison University have been making heuristic use of gaming and simulation for several years. In the fall of 1974, the college was awarded nearly $300,000 from the Lilly Endowment to continue and expand that heuristic use. Three years later, forms of simulation are being used by fifty per cent of the Denison faculty, and the college is becoming a center for the study of college-level applications of simulation.

This paper will discuss four major topics related to the Simulation Project: first, how the simulation concept has been defined so as to be of widest interest and applicability; second, how simulation can be linked to a problem-solving approach to learning; third, a short case history of how the previous two formulations were integrated in an extensive way into a traditional college curriculum; and fourth, a discussion of some of the attempts to evaluate these simulation efforts.

In September, 1974, Denison University was awarded a grant of $292,000 to establish a faculty development program aimed at introducing gaming and simulation into the college curriculum. Although ten or fifteen of the faculty were previously familiar with simulation methodologies, the concept of integrating the various subcategories of the process was general, rather than well-specified. To illustrate the orientation toward simulation, we quote from the proposal to the Lilly Endowment, which eventually funded the project.

> It is a basic objective of liberal education that there must be a working relationship between learning and the quality of an individual's life. We are committed to that objective at Denison; and because we are, we want, again and again, to stimulate students to perceive the practical value of what they are learning. We also want to enhance their personal confidence - - and their competence - - to use that learning with integrity and wisdom.
>
> We are impressed with simulation because it works directly on those objectives. It provides intensive training in problem-solving and decision making. It creates contexts in which complex questions of values and ethics may be addressed more effectively. It forces attention toward reality.

> Thus, simulation promises to help to close a gap too long neglected by liberal education. This is the gap between abstract learning and the application of what is learned. We are determined, according to the highest standards, to close that gap - - to stress the application of learning as well as abstract or theoretical understanding.
>
> Simulation helps to do that because it emphasizes the relationship between knowledge, principles and values and real situations, so that knowledge, principles and values are translated into understanding, decisions and solutions. In summary, then, simulation is a mode of education which demands that knowledge be integrated with reality and with behavior. It helps students to perceive values and ideas not as the material for arm-chair rhetoric, but rather as the bases of practical decisions and the touchstones of responsible action.
>
> [From "Simulation and Learning at Denison University," Granville, Ohio, 1974]

As can be seen, the major assumption in this approach is that simulation, in all its various forms, engenders or encourages problem solving. Is simulation consistent with a problem-solving approach? Does it actually encourage such an approach? This paper will attempt to respond to these questions, both at a theoretical level, and in terms of the empirical outcomes of trying to use simulation in such a way. We shall first discuss the problem of defining simulation, arguing that the various areas within simulation actually involve the same process, rather than many different ones. Second, we shall concern ourselves with the problem of defining problem solving, and linking that process with simulation. At that point we shall overview very briefly ways in which the preceding work with concepts of simulation and problem solving were integrated into much of the heuristic and research activity of a large percentage of the Denison faculty. Lastly, we shall ask about evaluating the validity of simulations, about their teaching effectiveness at the classroom level, as well as about the programmatic success of simulation used in a college-wide effort.

Defining simulation

For present purposes, role-playing, gaming, and simulation will be subsumed under the most general term of the three, simulation. All three activities involve building and/or manipulating models of systems. Since both "model" and "system" carry large numbers of connotations both concepts must be examined carefully.

The term "system" is used in numbers of jargon-filled analyses of phenomena of the social and physical sciences. Many of these used are derived either from the literature in systems analysis (e.g., White & Tauber, 1969) or from general systems theory (e.g., Laszlo, 1975). The concept of system in both these endeavors can be argued to be quite similar. In its simplest form, a system can be described as a set of structures, a set of relations among those structures, and a set of attributes (or properties). Relations among the attributes compose functions of the system (from Laszlo, 1975, p. 20). As Laszlo points out, there are seven principal types of systems: (1) the physicochemical (e.g., atoms, molecules, etc.); (2) the biological; (3) organ systems; (4) socialecological (formed by "energy and mass transfers of organisms within a geographic region"); (5) sociocultural ("distinguished by . . . a symbolic communication system, extraskeletal memory stores the . . . capacity to acquire, code and hand down empirically gathered information"); (6) organization (i.e., "formed by human beings . . . to carry out specific tasks"); and (7) technical systems ("made of suborganic components by organizations to carry out special purpose tasks within sociocultural systems.") Clearly then, any kind of phenomenon can be treated as a system. This fact, as will be seen opens the way for simulation to become a tool useable in most all classical disciplines, and to become an important tool for cross-disciplinary investigations.

What then is a model? In its broadest sense, a model is any form of description of a system. This means that, just as systems require concern with the component structures, relations among structures, attributes, and relations among attributes, a model of a system requires some form of representation of each of the four components. These required representations may take the form of verbal descriptions, physical "imitations," mathematical formulae, or computer programs.

The distinctions between role-playing, gaming, and computer simulation, then, can be said to occur largely as a function of the forms of models involved. An additional consideration, however, is that the level of specificity which characterizes the model may vary. This is to say that the degree to to which information about the components of the system are known and described in the model may vary. For example, when one simulates a jury deliberating a case, the legal structures are generally specified completely, but the personalities and decision-making characteristics of the jury are frequently left entirely unspecified. On the other hand, Forrester's (1969) elaborate computer simulation of a city specifies all the structures, relations, and so on, which its author considered relevant components of the urban system.

To simulate, then, is to model a system. Certainly this is a broad definition, and as such, it often brings the heuristic use of simulation under a peculiar form of fire. The criticism generally takes the form of "Then nearly everything one does in the classroom is simulation." An example of this criticism that is worth describing involves an English instructor who once told the present author he resented the fact that a student putting himself into the position of an historic character and then doing creative writing as that character, could be considered to be simulating. The response was that although the described activity did involve role-playing, there was probably only the most intuitive of attempts to identify and describe the components of any system. So, although

one of the forms or formats of simulation was there, the necessary analytic process that true simulation requires was not.

Two additional points should be made before leaving the definition of simulation, the first of which is not unrelated to the "everything is simulation" notion. There is existent much criticism of the heuristic uses of simulation on the basis of claims that it is the "fun-and-games" approach to learning, something only for the poorest students, or, in general, a tool which encourages only the lowest calibre of intellectual activities. The Denison Simulation Center contains one of the largest collections of games and simulations at the high-school or post-secondary level. Much of the material, it must truly be said that one would want to avoid. There exist in it inaccuracies, amazing over-simplications, and even some simulations with requirements for behavior that could only be termed offensive. This fact, however, ought not be allowed to discourage the instructor who is interested in treating complex problems in a sophisticated manner because, just as the heuristic simulation literature includes some of the worst materials and ideas, it clearly contains much of the best. Many social and physical scientists are finding simulation a powerful investigatory tool. The instructor working toward sophisticated conceptualizations of phenomena on the part of his students can therefore be expected to find simulation equally worthwhile.

An additional point that is important to note about the above discussion of what simulation is, concerns the fact that it is of broad applicability - - to the physical sciences, the social sciences, the humanities, and, though perhaps to a lesser extent, the arts. What the fact implies is that simulation allows it to be said that what the scientist is doing is related to what the humanist is doing. What is the exact nature of that link? We shall argue here that the main linkage flows from the simulation methodology moving all participants

toward active problem solving. Unfortunately, although most of the faculty now using simulation at Denison would argue similarly, it is clear that close questioning of these faculty may uncover only vague concepts of what is meant by "problem solving." And further, even these vague concepts are often inconsistent with each other. Before engaging in an attempt, therefore, to analyze simulation as a problem-solving technique, we must turn to the educational and psychological literature for more satisfactory clarification of problem solving.

Algorithmic Approaches to Problem Solving

A major difficulty in discussing problem solving concerns the fact that its usage varies so drastically from discipline to discipline, or even between research areas within a single discipline. In mathematics education, for example, the term generally refers to solutions of "word problems," enumeration problems, or problems from arithmetic, algebra, geometry, and so on. In these kinds of problems there are generally known solutions, or at least known algorithms to determine whether a solution exists, if not to determine the solution itself. An excellent example of an analysis of this kind of problem solving can be found in Wickelgren (1974). This psychologist and mathematician limits his theoretical treatment to solution of the above examples of "formal" problems, that is, those for which there are "ways of restricting thinking to a specified set of given information and operations" (p.2). Wickelgren differentiates specific problem-solving methods from general ones on the basis that the latter involves generalizing the application of a method from one problem to a non-identical other. For Wickelgren, solution of formal problems requires treatment of four major components: "givens," "operations for transforming givens," "goals," and "subgoals." Givens are a set of initial informational statements about whatever subject matter is being examined. Operations are the "actions" that can be taken to change or deduce from givens new informational statements. Goals are the

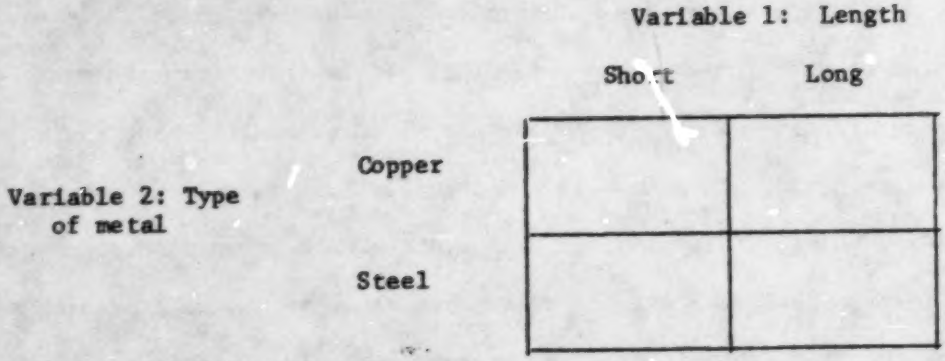
final statements which the problem-solver wishes to obtain. Subgoals are, just as one might imagine, informational statements which serve as way-stations toward goals. Wickelgren points out that subgoals are generally used to decrease the possible number of operations that must be tested to determine which ones provide progress toward goals. Finally, Wickelgren defines "insight" problems as those in which the solver makes a "critical transformation of the givens that essentially solves the problem," and he suggests that the insight form of problem-solving usually occurs in a small number of steps.

Another algorithmically-based, but somewhat more general concept of problem-solving is outlined by Glaser (1976). He uses Simon's (1969) distinction between "design" and "descriptive analysis" as an analogy for differentiating problem-solving and non-problem-solving approaches to education. Glaser points out that "the essence of design is to devise courses of action aimed at changing existing situations into preferred ones." Examples would include "devising a sales plan for a company, constructing a new social welfare policy for a state, and designing a program of instruction for a school system." On the other hand, "descriptive analysis" would presumably involve teaching material wherein student's major task is to understand and remember solutions which have been arrived at previously by someone else. Simon refers to this process as describing "how things are and how they work."

The main way in which Glaser's and Simon's approach to problem solving is similar to Wickelgren's is that mathematical optimization theory is suggested as a possible approach to teaching "design" activities. Given a goal, a set of parameter values (values of the initial states of the system), and a set of constraints, optimization procedures allow determination of an "optimal" set of values for the variables in the system (or, in other words, determination of the goal). An example might involve a game in which the player received a particular number of points if, after a certain base was named, he could reach that base

within thirty seconds. Given a set of points for each base, given the probability that any base is named, and given the relative spatial locations of each base, the optimization question would concern where the player would position himself for a maximum payoff in points (that is, the goal).

Another important approach to problem solving is one derived from theories about the psychological processes humans engage in when formulating the kind of algorithmic approach described above. Looking at numbers of these so-called "information-processing theories" of problem solving is beyond the scope of this paper, but one such model will be included since it adds much to our understanding of problem formulation. Suchman's Inquiry Training Model (1964) is based closely upon Piaget's (1926) model of intellectual development. A brief look at Suchman's work (a more elaborated introduction to his approach can be found in Joyce and Weil, 1972) indicates that he views problem solving as an operation carried out on concepts and schemas are brought into conflict with occurrences in his environment. The classic example of such conflict involves the child watching a strip made of two different metals laminated together. When turned in one direction over a flame, the strip bends upward. When turned in the opposite direction, it bends downward. The child must determine the series of events that would lead to such a "strange" outcome. To do so requires scientific problem solving, involving such steps as: first, determining what variables might be relevant to the problem (e.g., the length of the metal, its components, their response to heat); and second, setting up experiments to test the effects of those variables. In the metal strip example, the child might set up an experiment in which he examined the effects of two values on the variable "length" (long and short) and of two values on the variable "type of metal." This arrangement would result in a simple 2 x 2 factorial experiment of the following form:



The above description of inquiry training as a problem-solving approach looks, to this point, much like the algorithmic approaches discussed previously. Indeed, in a sense, it is somewhat algorithmic in nature. But its further assumption includes a stipulation that children at various stages of development go about using algorithms very differently. Only the child at the highest level of development (called "formal operations" by Piaget) would set up the appropriate experiment in the example of the metal blade. Younger children would not have the information-processing skills available for such an activity, and therefore would produce a developmental series of approaches, only when reaching "formal operations" coming to the proper experimental (or problem-solving) algorithm.

So it is in this sense that inquiry training is an information-processing model of problem-solving. The way, in fact, that it combines the algorithmic analysis of what problem <u>solutions</u> should look like, and the <u>thinking processes</u> through which one goes to reach those solutions is of major consequence to the present discussion. For surely the place where educators must eventually find themselves, exists at a point where both the form of problem solutions (or algorithms) <u>and</u> the information-processing occurrences that lead to those forms, are understood. And, if this claim is in fact true, then making the argument relating simulation and problem-solving requires examining

the effect simulation has both on algorithms, and the process of their creation.

Where do we stand at the end now of this overly brief comparison of approaches to problem-solving? Probably the major outcome is that there is at least a passing acquaintance with one general model for describing the setting of and solutions to problems: To combine Wickelgren's, Glaser's and Suchman's (or Piaget's) notions, it seems reasonable to say that problem-setting and solving requires analysis of given states of affairs, knowledge about rules and constraints for possible manipulating of those states, and an analysis of what one wishes to accomplish. This process could be carried out by setting up a mathematical optimization problem, structuring a logical (deductive or inductive) argument, or formulating hypotheses and an experiment to test them. It should be noted, of course, that such an approach assumes most problems can be treated as if they were, in Wickelgren's terms, formal ones.

PROBLEM-SOLVING AND SIMULATION

As can be seen in the above admittedly biased review of some approaches to problem-solving, there is little theorizing about complex problem-solving processes which can be easily applied to the practical concerns of incorporating the process into one's teaching activities or into the learning processes of one's students. Where college instructors are claiming to use problem-solving approaches, their analyses of both the problem-solving algorithms and the problem-processing activities of their own systems and those of their students seem to remain largely at an intuituve level. What then, the reader may well be asking himself, is the special merit of simulation as a problem-solving tool? The answer is straight-forward in some respects. Simulation is the design and analysis of systems. Whatever the structure of problems and their solutions is, and whatever humans do when they set and solve problems, are identical to the structures and processing of simulation. Simulation <u>is</u>

setting and solving problems--but to simulate, that is, to do it well, requires a reflective analysis of what one is doing. Casting this idea into other words, expert simulation requires self-knowledge about one's problem-processing activities. And further, the argument will be made that this self-knowledge enhances the ability to transfer problem-processing from one domain to another.

We must now elaborate upon the notion that to simulate is to engage in problem-solving. Under the assumption that simulation involves a model of structures, relations among structures, attributes, and relations among attributes, its relations to algorithmic analyses of problem-solving like those of Wickelgren and Glaser become immediately clear. For example, assume it was desirable to create a simulation of pattern-recognition processes on the skin (Thorson, Snyder, Anderson, & Thorson, 1976). A reasonable first step would be to list the "givens" or rules about skin structures, and the limits of information-handling by the cutaneous system (e.g., the receptors in the skin, the way information is sent into the spinal column, or the way in which the sensory cortex is arranged.) These givens would correspond to structures. Next, the relevant operations would have to be hypothesized (e.g., stimulation of one area of the skin will inhibit sensory registration at other areas.) The hypothesized operations would here correspond to relations among the structures. (Whether it would be necessary to separate attributes from relations among structures is not clear, so in this case that distinction will not be made.) The goal might be stated in terms of a model of cutaneous processing for which, given any patterned input (e.g., a letter drawn on the skin) the system either recognizes it accurately or does not. Since the cutaneous literature does not yet provide empirical examples of all relevant inputs to the skin, a justifiable subgoal would be to ask the model to predict accurately examples of cutaneous input which are actually available for empirical verification.

This example, then, hopefully provides a straight-forward argument that the steps in setting and solving problems are, in important ways, identical to the steps in building a simulation. Unfortunately, the reader may now be commenting, the link between simulation and problem-solving might be relevant for the research scientist, but surely one cannot expect the undergraduate student to build such a simulation. And if he does not build the simulation himself, he is not participating in problem-solving. Two responses to this comment seem appropriate. First, it does seem justifiable to claim that modeling a system is problem solving in one of its most sophisticated forms. But problem-solving of what Wickelgren calls formal problems can be argued to be quite similar to working through predictions in an already-formulated simulation. The cutaneous model can again be used as an example. Assume the model has already been formulated, and, in fact, its structural and relational characteristics are all available in the form of an interactive computer program. In that case, of course, the student does not have to formulate all of the givens or operations, although he does have to come to understand them. What he does have to do, if his instructor is wise in using the simulation, is set up goals and/or subgoals for (1) choosing inputs to the simulation that will allow him to understand better how it works; (2) predict how the simulation will respond to the inputs; and (3) as he carries out 1) and 2), actually rediscover additional relations existent in the model and which may not have been given to him in their entirety as he began. So even though the cutaneous problem is now a more formalized one (that is, having, more nearly, an enumerable set of alternative strategies) it is still not perfectly formal. In other words, the student working with a developed simulation still remains largely in the role of the original problem-solver. A major advantage, however, is that he can be given varying amounts of prior information, so that at the beginning of his endeavors, his problem-solving skills are not required to emerge fully developed.

Introducing Simulation into the College Curriculum

The preceding sections of this paper have attempted to formulate fairly specifically just what simulation is, and how it relates to problem-solving approaches to higher education. Once the justification and defining stages of curricular developments are completed, the next step, of course, is to introduce changes into the work and research of faculty and students. The experience at Denison seems especially interesting in that it involves more extensive integration of simulation into all portions of college life than has been accomplished elsewhere.

To discuss activities of introducing change, two kinds of occurrence are relevant. The first concerns how to communicate enough information to others for them to become willing to make some personal attempts at the necessary re-education processes. Such communication is partially an intellectual process, but more extensively it is political. A well-elaborated description of that process at Denison is available in an article by Ledebur (1975) who directed the Simulation Project during its first year.

The second kind of occurrence relating to introductory processes concerns what programmatic structures come into existence. Because these have not been discussed previously, they will be treated briefly here. Five primary occurrences are included in the group of programmatic structures: a) consultants; b) workshops; c) faculty development programs for developing classroom and research applications of simulation; d) stimulation of production of written papers and materials; and e) a system of classroom and program evaluation.

The initial decision about encouraging faculty to take advantage of the opportunity to learn about simulation involved the presumption that the most exciting approaches in the field are those wherein sophisticated research applications are being made. It was decided, therefore, to create a program of visiting consultants, including primarily prestigious researchers and authors who

happened to use simulation as a major methodology, but who were not necessarily schooled in heuristic applications. Consistent with this approach, was the assumption that Denison faculty, once excited by the possibilities of simulation as a problem-solving tool, would be able to formulate their own heuristic applications.

Although we have no way of comparing the success of the resultant program of visiting simulation experts to other possible structures, many of the now-involved Denison faculty report their interactions with consultants to have been pivotal in their decisions toward experimentation with the approach. To mention but a few of the more than fifty simulation experts who proved so effective there were representatives from psychology such as William Bewley (Minnesota Educational Computing Consortium), Philip Spelt (Wabash College), and Dana Main (West Virginia College of Graduate Studies); from sociology, Cathy Greenblat (Rutgers College); from geology, John Harbaugh (Stanford University); from mathematics and engineering Maynard Thompson (Indiana University); from international relations, Margaret and Charles Hermann (Ohio State University), Karen Feste (University of Denver); history, Robert Hauser (Pennsylvania State University at McKeesport); from education, Charles Plummer (University of Illinois) and Donald Cruickshank (Ohio State University); from chemistry, Norman Craig (Oberlin) and William Child (Carleton College); and from women's studies, Rosabeth Kanter (Brandeis University).

All of these individuals have made significant contributions to their field, and their expertise and sophistication in using simulation was responded to strongly by Denison faculty.

A second form of simulation activity which seemed to have major impact upon introduction of change into the curriculum were workshops. For the most part, these workshops were organized around special topics related directly or as helping tools to simulation approaches. In most cases, the workshops were organized by a single Denison faculty person, who invited consultants and/or

used resource persons from the campus. Many of the workshops involved faculty participants from other schools; some were only for the local constituency. A few directly involved students. Examples of these workshops include such topics as "Simulation in Chemistry," "Simulation of Reasoning Processes in Children," "Cognitive Styles and Simulation," "Simulation in Assertiveness Training," Simulation and the Roles of Professional Women," "Simulation and Racial Relations," as well as many others. In addition to these special topic activities, the Simulation Center presented a wide-ranging summer workshop last year, including all the areas of application that had been developed, and, we plan in fact, to present another such workshop in June, 1977.

There are two major payoffs for investing in these forms and varieties of workshops. The first is that they create a rich source of information dissemination. Since simulation as an heuristic tool is a fairly new endeavor, it is an area that often requires direct communication, rather than filtering through journal articles. Too, the area is so diverse, that only individuals gathered from a variety of areas and representing many backgrounds can assure inclusion into one's own repertoire all the myriad examples and ideas. And secondly, organization of workshops requires organization of one's own resources, as well as expansion of these resources. The requirement to "produce" for others, then, serves as a strong motivating force. Overall, then, workshops uniquely allow both expansion and integration of activities in simulation.

A third activity aimed at introducing simulation into the curriculum involved summer and semester released-time grants for individual faculty work in simulation. Nearly seventy such grants have been made at Denison, thereby allowing a large number of faculty to experiment with simulation activities in their own fields, and to recast these activities into a form usable in their

classrooms. The faculty development program involves, then, incentives and provides the time that is necessary for creating sophisticated applications.

Coordinate with the faculty development program has been the assumption that those who were provided the opportunities would share the proceeds, in terms of papers, articles, essays, computer programs, and games, with others. To date, the Denison Simulation Center has available more than a hundred such products. Denison faculty are actively reporting their work both within disciplinary forums and to educational groups. A sampling of the projects is contained in Appendix I of this paper.

The final introduction format to be discussed here is the notion that whatever is developed, be it computer simulations, a game, an integration of course materials with a set of games, or an interdisciplinary course formed around a complex simulation, it must be evaluated, at least in some manner. Educational and curricular evaluation are always difficult. Nevertheless, the difficulty has not seemed sufficient to warrant ignoring evaluation, and at least one-fourth of the simulation activities at Denison have been subjected to evaluational scrutiny. Because Morris's (1977) paper analyzes much of the classroom evaluation occurring at Denison, the remarks herein about evaluation will remain fairly general. An elaboration of our philosophy of evaluating simulations and their heuristic use is contained in the final section of this paper.

Evaluation of Simulations and their Heuristic Use

As the present author has argued previously (Thorson, 1977) evaluation of a simulation and evaluation of its effectiveness when used in the classroom are two very different enterprises. For that reason, they will be treated separately, though briefly, in the following paragraphs. The goal here is to outline what we have attempted to accomplish in "evaluating" simulation activities at Denison.

Evaluation Level I: Validation of Simulations and Games

Surprisingly little research has been aimed directly at the problem of validating simulations and games. One of the most extensive logical analyses of the simulation validation techniques was done by Hermann (1967). He was concerned with defining rules for establishing the scientific validity of simulations and games, applying his analysis to some of the early models of international politics. According to Hermann, two initial kinds of specification of simulation must be made before it can be validated. First, what type of simulation is it: man, man-machine, or machine? Second, to what purpose will it be put to use: a) as an instrument for discovering and defining alternatives for processing activities, for policy, etc.; b) as a model which produces accurate predictions about future events; c) as an instructive device; d) as a mechanism for formalizing theories and hypotheses, and perhaps "pre-testing" them; e) or [presumably] for some combination of these purposes. It is important to note that Hermann made two suggestions for validation of simulations used as instructive devices. First, he suggested they should not "transmit systematic misperceptions . . . of the reference system involved in the instructional program" and second, they should "provide the student with greater empathy for those persons who operate in the reference system being simulated" (Hermann, 1967, p. 218).

Once the type and purpose(s) of the simulation or game have been established, the degree of validity exhibited by the simulation can be ascertained. Hermann emphasized three kinds of validity: face, internal, and event. Face validity involves the "intuitive convincingness" of the simulation, or how "realistic" it appears to be. Internal validity involves having the rules contained in the simulation or game fit together in a logically consistent way. Event validity is defined similarly to Campbell's (1957) notion of external validity; that is, that "natural" events occur in the same relations to each other as do the events in

the simulation. Hermann's work in analyzing validity-establishment procedures for simulations, though not the only such approach, does provide a reasonable overview of questions to ask of the structures and functions of simulations and games. (For a similar treatment of the validity problem, with an emphasis upon economics, see Naylor, Blintfy, Burdick, and Chu, 1966)

Hermann's approach, however, is not totally appropriate for establishment of validity for simulations still in developmental stages. Further, validation or at least partial validation of simulations that are not fully formulated is important, since these simulations are often used for heuristic purposes, and since it is important for further investigation that a researcher be able to evaluate the simulation or game as it progresses toward final formulation. Although in some ways an even more complicated issue, some suggestions for validating in-progress simulations were made by Thorson, Anderson, and Thorson (1975). Two of these suggestions will be mentioned here. First, ideally, each variable in the simulation should be provided with more than one operational definition, and these definitions should converge in the sense that relations between other variables and the two or more operational definitions indexing the one variable should be consistent. For example, if the number of persons per bathroom and the number of persons per housing unit both serve as operational definitions for "crowding," then measures on "psychosis levels," if related to one operational definition of crowding, must in a like manner be related to the other one. The second criterion for establishment of the validity of in-progress simulations requires that not only the inputs and outputs of the simulation or game be accurately reflective of actual occurrences, but that the structures

and functions intervening to connect certain inputs with certain outputs also be accurate. For example, in an international relations simulation, two countries, one highly industrialized and having a large bureaucracy and the other, having neither characteristic, may both exhibit the same response to a particular international crisis, but to claim the two responses were mediated by the same internal system would clearly be unsatisfactory.

Other analyses have been written on the topic of validating simualtions, and although time is not sufficient to discuss those works here, some of the more notable examples include Kress (1965), Coplin (1966), and Guetzkow (1968), all of whom worked in the area of international relations. A more recent, though abbreviated, discussion is available in Greenblat (1975).

Evaluation Level II: The Teaching Effectiveness of Simulations and Games

Once some indication has been established regarding the validation of a simulation or game, the next level of educational evaluation concerns how well the devices "teach." The question of "teaching effectiveness" is, at Denison, as in most all teaching institutions, a controversial one. Parlett and Hamilton (1972) characterize quite well the general nature of the controversy. (Although these authors are referring to program evaluations, their suggestions apply equally well to evaluations of teaching effectiveness.) Many educators, they suggest, advocate the experimental/psychometric approach, in which pre-test measures are compared statistically with post-test measures to determine whether an intervening "treatment" (such as the use of simulations) has had an effect. A position polarized against this one is the "humanistic" approach which generally claims that processes occurring in educational environments are simply too "complex" for scientific study (at least with techniques currently available), or that the educational processes are a priori not amenable to scientific investigation. The position intermediate to the humanistic and

psychometric ones is that orientation referred to by Parlett and Hamilton as the social-anthropological approach. This approach would claim that educational outcomes can be investigated, but that the psychometric approach is unsatisfactory for a number of reasons. First, in educational research the number of relevant variables seems to be quite large. In psychometrics, there are two techniques for handling these numerous variables. First, it can be assumed that by using large samples, many of the variables' effects will be randomized so as to have essentially an equal effect in every experimental group. Large-sample techniques are, however, difficult to set up satisfactorily, and often impossible to use in the setting of one particular class, several classes, or even in the entire institution. A second way to treat the "number of variables" problem involves maintaining strict experimental control over all the relevant variables. Here again, however, the problems are great. First, the researcher must be able to identify all the relevant variables - - which is certainly a difficult, if not an impossible task. Secondly, he must manipulate students and educational personnel in ways which may prove ethically unacceptable to many. Finally, the strong possibility exists for creating "artificial" environments where the results are not generalizable to the educational situation in which the researcher was originally interested.

Another criticism of the psychometric approach is that it requires that there be no changes in the "treatment" (e.g., the simulation procedure) while the experiment is in progress. In an educational environment, however, it can be argued that few, if any, procedures are developed to the stage where the instructor can or is willing to forego occasional changes.

Perhaps the most important of Parlett and Hamilton's criticisms of the psychometric method concerns the fact that by emphasizing scientific methodology too strongly the researcher is led to ignore many occurrences or kinds of variables which because of their "subjective" nature, are difficult to study.

In examining the educational research literature, one does frequently receive the impression that many studies are well-controlled, but have omitted so many possibly pertinent variables that the studies are simply uninteresting and unconvincing. Other studies attempt to ask difficult questions, but the methodology includes so many confoundings that the results again are not useful.

The approach Parlett and Hamilton suggest as a replacement for psychometric evaluations involves three basic procedures. First, the initial analysis and description of the technique to be evaluated must be expanded to include both subjective and objective methods. For example, various kinds of interviews with major actors involved in the educational innovation should be extensively employed. Both unobtrusive (Webb, 1966) and participant (McCall and Simmons, 1969) observation methods should be used. Generally then, better identification of relevant variables can occur. Secondly, the researcher should make every attempt to find out into what kind of environment (or "learning milieu") the teaching device is being introduced. This environment, then, should be the one in which the treatment is tested, rather than testing it in a more easily handleable, but unfortunately artificial environment. Finally, it is suggested that the kind of educational method being used determines how it is tested, rather than the methodology itself being the first concern.

Parlett and Hamilton's description of the humanistic and psychometric approaches to evaluation of teaching innovations is quite helpful, and their suggestions for an intermediate approach are interesting for the present problem of evaluating the teaching effectiveness of simulations and games. We argue here, however, after all their suggestions are taken into account, essentially the same psychometric approach is being advocated. What has been added are more important considerations for making psychometric methodologies more sophisticated and therefore making their outcomes more intuitively convincing.

Such a "modified" psychometric appraoch is the one currently being used in all of the Denison projects evaluating the teaching effectiveness of simulation and gaming applications. Basically pre-test and post-test measures are being taken and compared, but for each project the kinds of measures being used vary considerably. In fact, Morris (1977) points out specifically in his paper on evaluating the teaching effectiveness of simulation, that differences in both the purposes of using simulation and the form of simulation being used require variation in what measures are most appropriate.

Although, as pointed out above, evaluational activities have accompanied many of the Denison simulation projects, the present section of this paper would not be complete without providing at least one example of how the two levels of evaluation elaborated here, can and have been analyzed. The example to be used is especially informative because its purpose was to test whether working with simulations would allow the students' problem-solving skills to develop and transfer to new situations.

Paul King, a Denison economist, compared in two classes two differing approaches to teaching macroeconomics (King, 1976) in one class, a textbook-plus-lecture method was used. In the other, students worked with the same text, but spent a significant portion of thier class times working with computer simulations of various macroeconomic phenomena. The developmental emphasis in this class involved first understanding the models, then understanding their structures and how the instructor had come to formulate those structures, and finally, it required the students to create their own models.

To determine whether the two groups would show differing degrees of change in their "general problem-solving skills," the pre- and post-tests included questions requiring that just such generalizations occur, for the student to receive full credit. One of the instruments used to ask this

question divided test questions into "simple applications" of principles and "complex applications." Both kinds of application essentially required the student to formulate and use models to suggest solutions to new, though related, economic problems. Compared with national norms for the test, both the control and the simulation classes performed fairly well on the complex applications but not as well as on the simple applications. Importantly, however, on the simple applications, the simulation class was significantly better. This outcome provides, then, one at least initial indication that work with models, together with analysis of the information-processing occurrences in formulating them, can lead to transfer of problem-solving skills. In addition, however, the result led King to question the validity of the set of simulations he had used, especially with regard to their lack of complexity. Therefore after completion of his project, he rewrote the simulations, making them much more complex. He is now engaged in replicating his evaluational study, using what he believes to be "more valid" macroeconomic simulations.

What we see here, then, is an instance of work evaluating both the validity and the teaching effectiveness aspects of a set of simulations. The outcomes in this example seem to us highly encouraging for the general orientation the Denison Simulation Project has taken toward evaluation.

Some Conclusions

The present paper has outlined the essential assumptions and structures involved in conceptualizing, implementing, and evaluating a wide-ranging program of simulation at the college level. Can we talk yet about the overall outcome or success of such an enterprise? Certainly in a short-term sense, some characteristics of success are present. Nearly half of the teaching staff is using or has used simulation. Most of the faculty have created their own simulations, or improved considerably upon existent simulations. There have been major efforts to

monitor through evaluation of their validity and teaching effectiveness, many of the simulations used. New courses and interdisciplinary courses have been created. Clearly, then, the short-term or immediate response about the project would be positive.

But what of the long-term consequences? Will Denison students prove themselves better problem-solvers after graduation? Will the faculty continue to create and use simulation? Will the impetus toward evaluation continue? These questions seem of primary importance, and, of course, they cannot yet be answered. Given our present state, we think the prognosis looks encouraging. We hope to be able to continue a basically analytic approach to simulation in the years to come, and thereby eventually to find and report some answers to these long-term questions.

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Appendix I: A Partial Listing of Simulation Projects in Higher Education from the Denison Simulation Center

Bigelow, Bruce, Gordon, Amy, and Gordon, Michael. History, Values and Simulation.

Bowling, Susan R., and Brakeman, Louis F. Designing a Liberal Arts College for the Future.

Clayton, Dorothy. An Evaluation and Modification of the NEW ALEXANDRIA GAME.

Fletcher, Daniel O., and Karian, Zaven A., and Castor, Richard L. Simulation of a Regulatory Commission.

Gallant, Thomas F. A Comparative Study of Three Instructional Approaches: Self-Paced Learning Materials Packages, Simulation Gaming, and Competency-Based Behavioral Tasks.

Goldblatt, David A. Values and Critical Communication.

Klatt, Kenneth P. The ATP Game: Design and Development of a Simulation of Metabolic Control.

Laird, Judith, and Straumanis, Joan. JOB CRUNCH, The Affirmative Action Game.

Ledebur, Larry C. The Impact of Simulations on Value Systems of Students.

Norris, Gail. Radiation Biology and Radiation Dosimetry.

Potter, David L. A Review of Some Urban Simulations and Games and an Assessment of Utility.

Preston, Naomi E., and Hudson, Barbara L., and Thios, Samuel J. Educational Cognitive Style as a Factor in Learning Through Simulation.

Slesnick, Frank. Simulation in the Managerial Finance Curriculum.

Sorenson, David S. Nuclear Deterrence: A Simulation of Defense Policy-Making.

Thios, Samuel. Educational Implications of Cognitive Style Research.

Thorson, Esther. Simulation in the Liberal Arts College: Evaluation at Three Levels.

Wismer, Robert L., and Gilbert, George L. Simulation in Chemical Education.